The Global Precipitation Measurement (GPM) Mission: An Overview

Arthur Y. Hou

NASA Goddard Space Flight Center
arthur.y.hou@nasa.gov

Mission Concept
Instrument Capabilities
Ground Validation
Mission Status

2006 EUMETSAT Meteorological Satellite Conference
Helsinki, Finland, 12-16 June 2006

Water is fundamental to the life on Earth

Its transition between the gaseous, liquid, and solid states dominates the behavior of the Earth system

Precipitation converts atmospheric water vapor into rain and snow …

and is a central element of the global water cycle and the primary source of freshwater

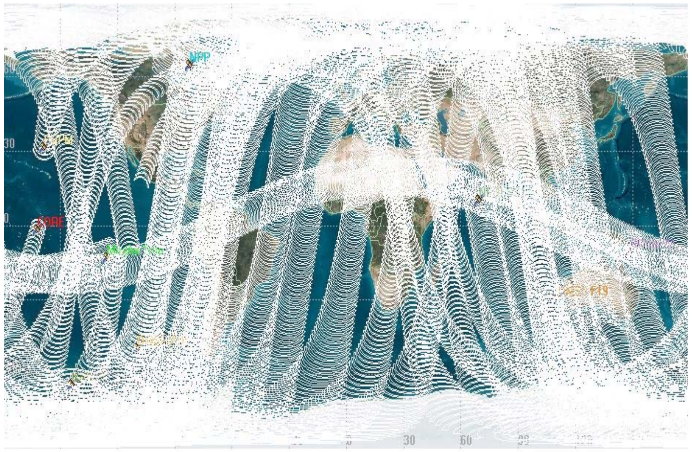
Accurate and timely knowledge of global precipitation is essential for

- *understanding the integrated weather/climate/ecological system*
- *managing freshwater resources*
- *monitoring & predicting high-impact natural hazard events*

GPM is an international satellite mission to provide *uniformly-calibrated precipitation measurements every 2-4 hours around the globe*

A science mission with integrated applications goals

GPM Core + 7 Constellation 3h Coverage



GPM Science Objectives:

- *Advancing precipitation measurement capability from space*
  - active and passive remote-sensing techniques
- *Advancing understanding of global water/energy cycle variability and fresh water availability*
  - better measurement of the space-time variability
- *Improving weather forecasting skills*
  - more accurate & frequent instantaneous rain rates
- *Improving climate modeling and prediction capabilities*
  - better understanding of precipitation microphysics, surface water fluxes, & soil moisture storage
- *Improving prediction capabilities for floods, landslides, freshwater resources, and other hydrological applications*
  - improved temporal sampling spatial coverage

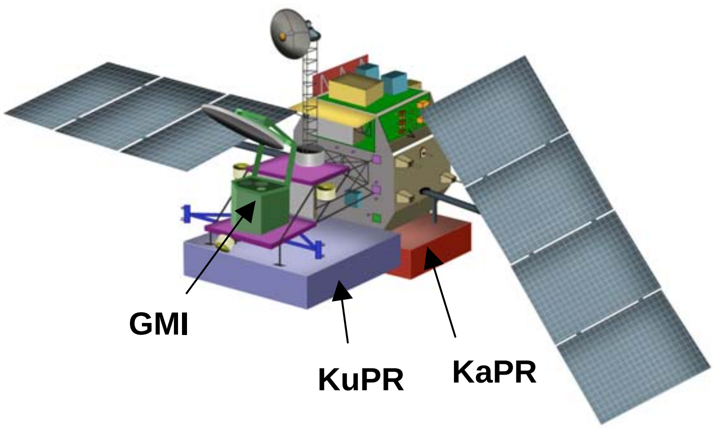
Role of GPM in Global Precipitation Measurements

- GPM Core Spacecraft provides combined radar/radiometer measurements of 3-D precipitation structures and microphysical properties to serve as

1) a precipitation physics laboratory for improved understanding of precipitation processes and retrieval algorithms and

2) a reference standard for unifying measurements from a heterogeneous constellation of dedicated and operational satellites with passive microwave radiometers and sounders.

- A NASA constellation in a low-inclination orbit to improve real-time monitoring and prediction of hurricanes



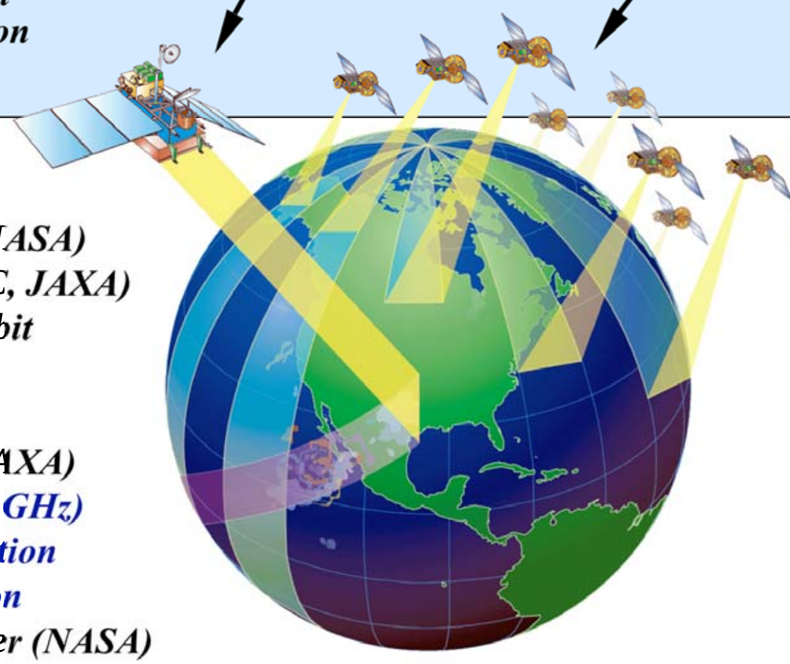
GPM Reference Concept

OBJECTIVES

- Understand horizontal & vertical structure and microphysical properties of precipitation, and associated latent heating
- Train & calibrate retrieval algorithms for constellation radiometers

OBJECTIVES

- Provide global coverage and temporal sampling to improve rainfall accumulations and real-time precipitation monitoring
- Extend scientific and societal applications



Core Satellite

- TRMM-like spacecraft (NASA)
- H2-A rocket launch (TBC, JAXA)
- Non-sun-synchronous orbit
  - ~ 65° inclination
  - ~407 km altitude
- Dual frequency radar (JAXA)
  - Ku-Ka Bands (13.6-35.5 GHz)
  - ~ 4 km horizontal resolution
  - ~250 m vertical resolution
- Multifrequency radiometer (NASA)
  - 10.65, 18.7, 23.8, 36.5, 89.0, 166, 183.3 GHz

Constellation Satellites

- Pre-existing operational-experimental & dedicated satellites with PMW radiometers & sounders
- Revisit time
  - ~ 2-4 hour at > 80% of time
- Sun-synch & non-sun- synch orbits
  - 600-900 km altitudes
- A real-time hurricane monitor in a low-inclination orbit (TCB, NASA)

Ground Validation Sites

- Ground measurement & calibration
- Cooperative international partners

Precipitation Processing System

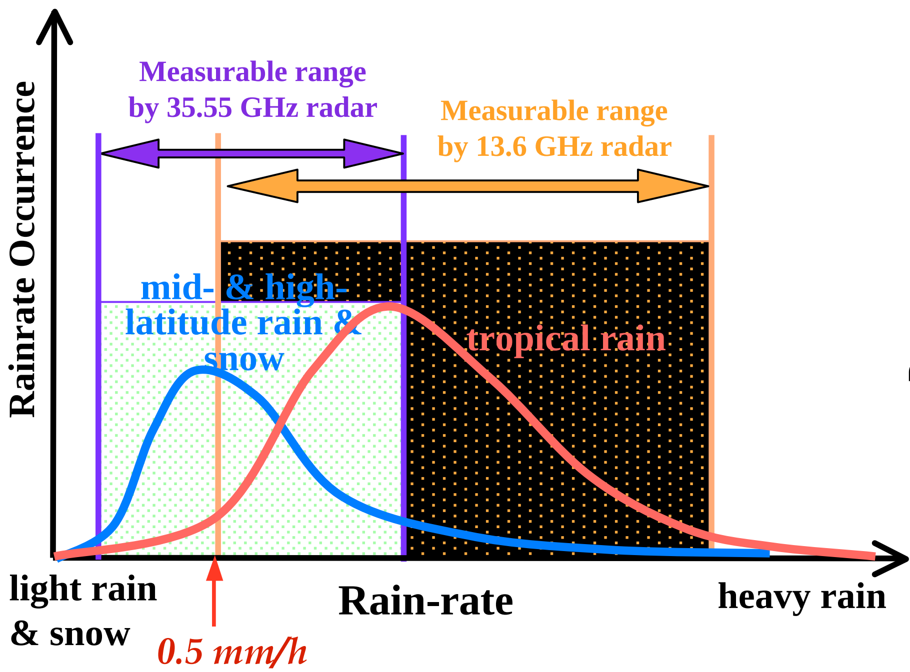
- Global precipitation products from input data provided by a consortium of cooperative international partners

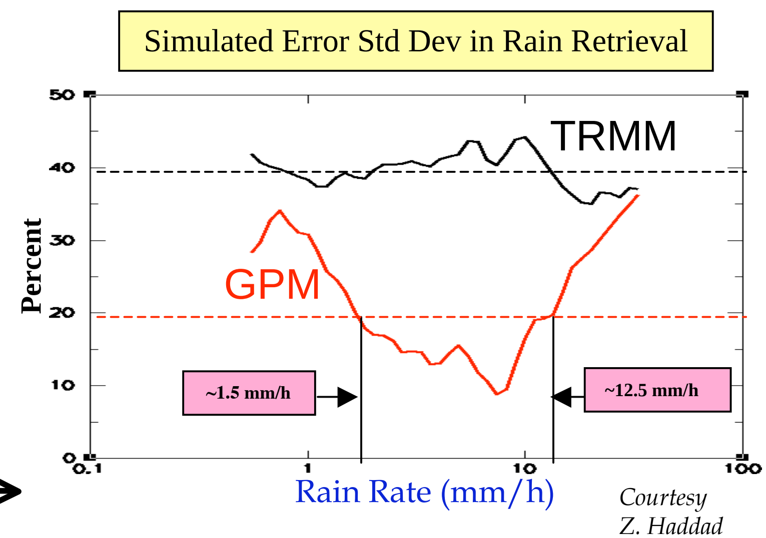
GPM Sensor Capability: Dual-Frequency Precipitation Radar

New Challenges: Measuring light rain and snow

DPR Advances over TRMM PR

- *Increased sensitivity for light rain and snow detection* – extending the detection threshold from 18 to 11 dBZ (0.5 to 0.17 mm/h)
- *Better overall measurement accuracy* - replacing the surface reference technique for path-integrated-attenuation correction with dual-frequency methods
- *More detailed microphysical information* – estimation of drop size distribution and identification of liquid, frozen, and mixed phase precipitation to provide an improved cloud database for rain & snow retrievals for both the Core and constellation sensors

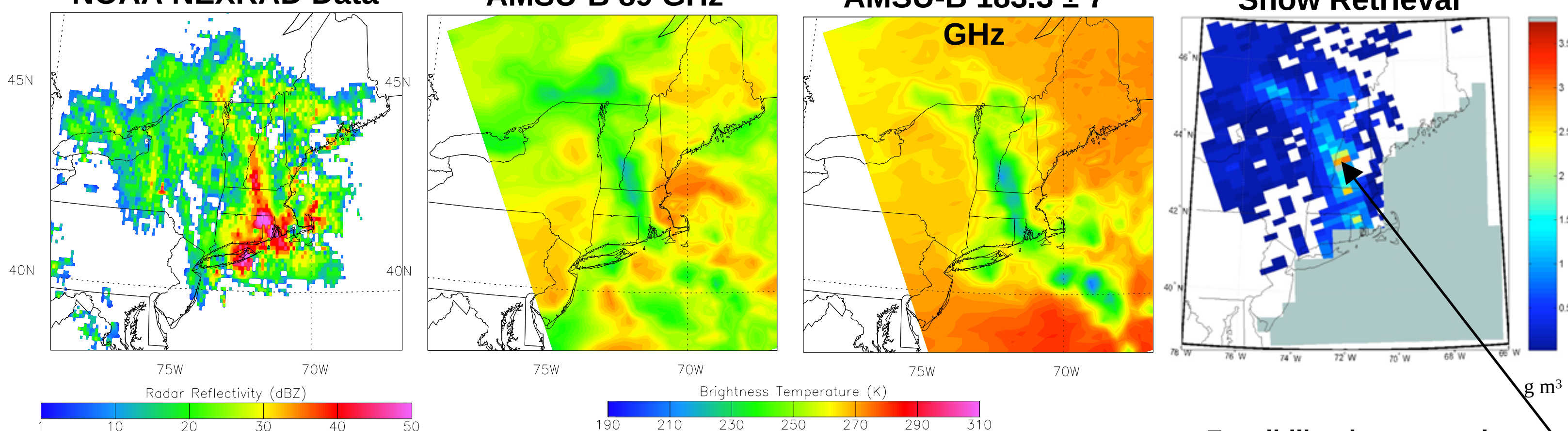




GPM Microwave Imager with HF capabilities

- *Measuring light rain*
- *Measuring frozen precipitation*
- *Improving retrieval algorithms over land*
- *Enabling the testing and evaluation of constellation radiometer algorithms using the DPR on GPM Core*

NOAA NEXRAD Data | **AMSU-B 89 GHz** | **AMSU-B 183.3 ± 7 GHz** | **Snow Retrieval**



Radar reflectivity composite of the March 5-6, 2001 New England blizzard (75 cm of snow fell on Burlington, VT)

Surface effects evident over the Great Lakes, the St. Lawrence River, and along the Atlantic coast. Cannot distinguish surface from cloud effects.

Surface effects screened by water vapor. Snowfall appears over New England as low brightness temperatures

Feasibility demonstration of snowfall retrieval using HF channels 4 in/hr

Courtesy of G. Skofronick-Jackson

Passive Microwave Sensor (PMW) Characteristics

Constellation microwave sensor channel coverage

V – Vertical Polarization
H – Horizontal Polarization
R - Right Circular Polarization
L – Left Circular Polarization
P – Plus 45 degrees
M – Minus 45 degrees

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183/190 GHz
AMSR-E	6.925 V/H	10.65 V/H	18.7 V/H	23.8 V/H	36.5 V/H		89.0 V/H		
CMIS	6.625 V/H	10.65 H/R/L	18.70 V/P/M/R/L	23.8 V/H	36.5 V/P/H	50.3-60.44 V/L	89.0 V/H	166 V	183.31 V
GMI		10.65 V/H	18.70 V/H	23.80 V	36.50 V/H		89.0 V/H	165.5 V/H	183.31 V
MADRAS			18.7 V/H	23.8 V	36.5 V/H		89.0 V/H	157 V/H	
SSMIS			19.35 V/H	22.235 V	37.0 V/H	50.3-63.28 V/H	91.65 V/H	150 H	183.31H
MHS							89 V	157 V	183.311 H 190.311 V
ATMS				23.8	31.4	50.3-57.29	87-91	164-167	183.31

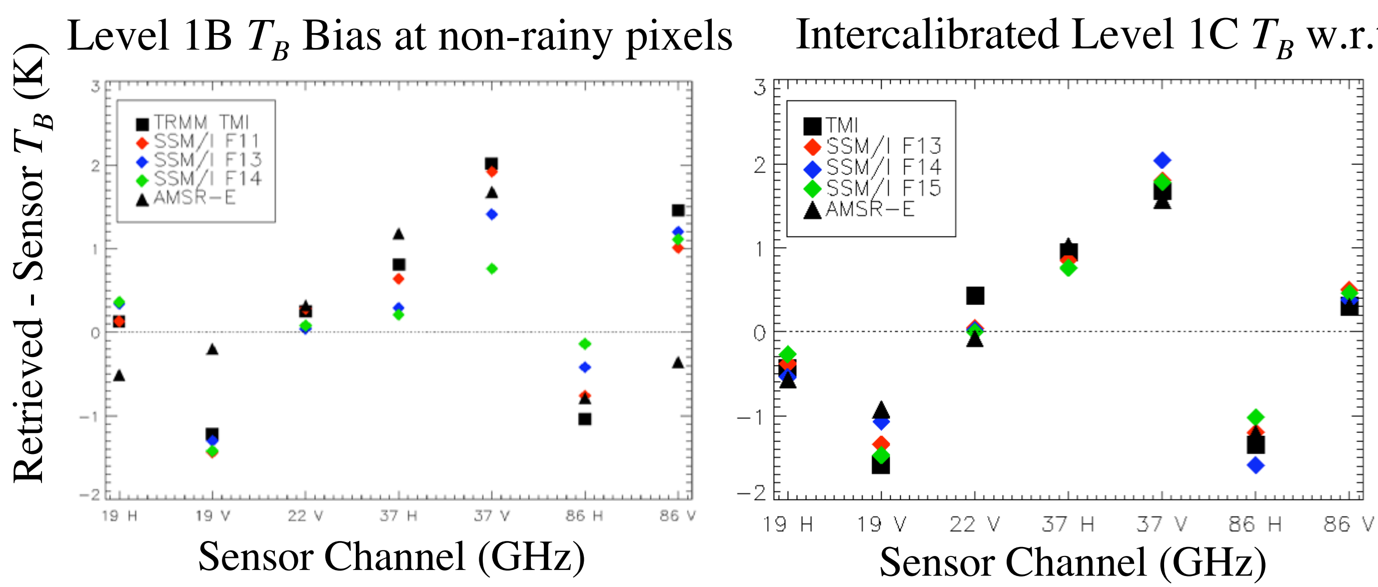
Mean Spatial Resolution (km)

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183 GHz
AMSR-E	56	38	21	24	12		5		
CMIS	54	38	20	15	14	14	14	14	14
GMI		26	15	12	11		6	6	6
MADRAS			40	40	40		10	6	
SSMIS			59	59	36	22	14	14	14
MHS							17	17	17
ATMS				74	74	32	16	16	16

Different center frequencies, viewing geometry, and spatial resolution must be reconciled

GPM provides a consistent framework for a heterogeneous constellation of PMW sensors to produce uniformly-calibrated global precipitation estimates

GPM Core acting as the reference standard to intercalibrate constellation measurements at both radiance and retrieval levels



Coincident sensor T_B calibrated to simulated TMI T_B

Courtesy of C. Kummerow

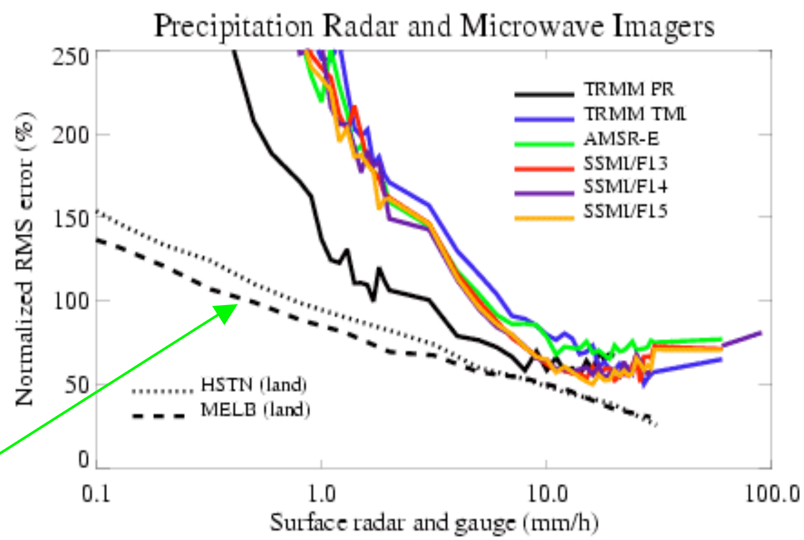
Using DPR+GMI on GPM Core to calibrate coincident T_B's rainy and non-rainy pixels and to provide a common cloud database for precipitation retrieval

Level 1C homogenizes existing Level 1B for precipitation retrieval without replacing official L1B products

An open community effort: http://mrain.atmos.colostate.edu/LEVEL1C/

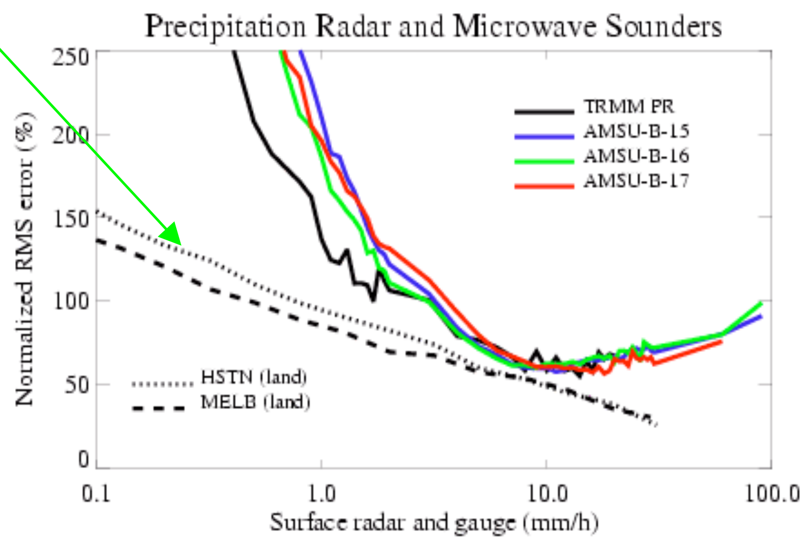
Comparison of Surface Rain Retrievals from Passive Microwave Radiometers and Sounders

Estimated RMS errors due to temporal mismatches within 1h observation window for perfect retrievals



Normalized RMS errors of TMI, AMSR-E, F13, F14, & F15 relative to TRMM PR against ground measurements over U.S.

0.25º instantaneous retrievals within hourly windows against continuous surface radar & gauge measurements for JJA 2005



Corresponding errors for AMSU-B (15, 16, 17)

Sounder retrievals with HF channels are closer to PR than radiometers between 1-10 mm/h

In GPM era both radiometers & sounders have HF channels

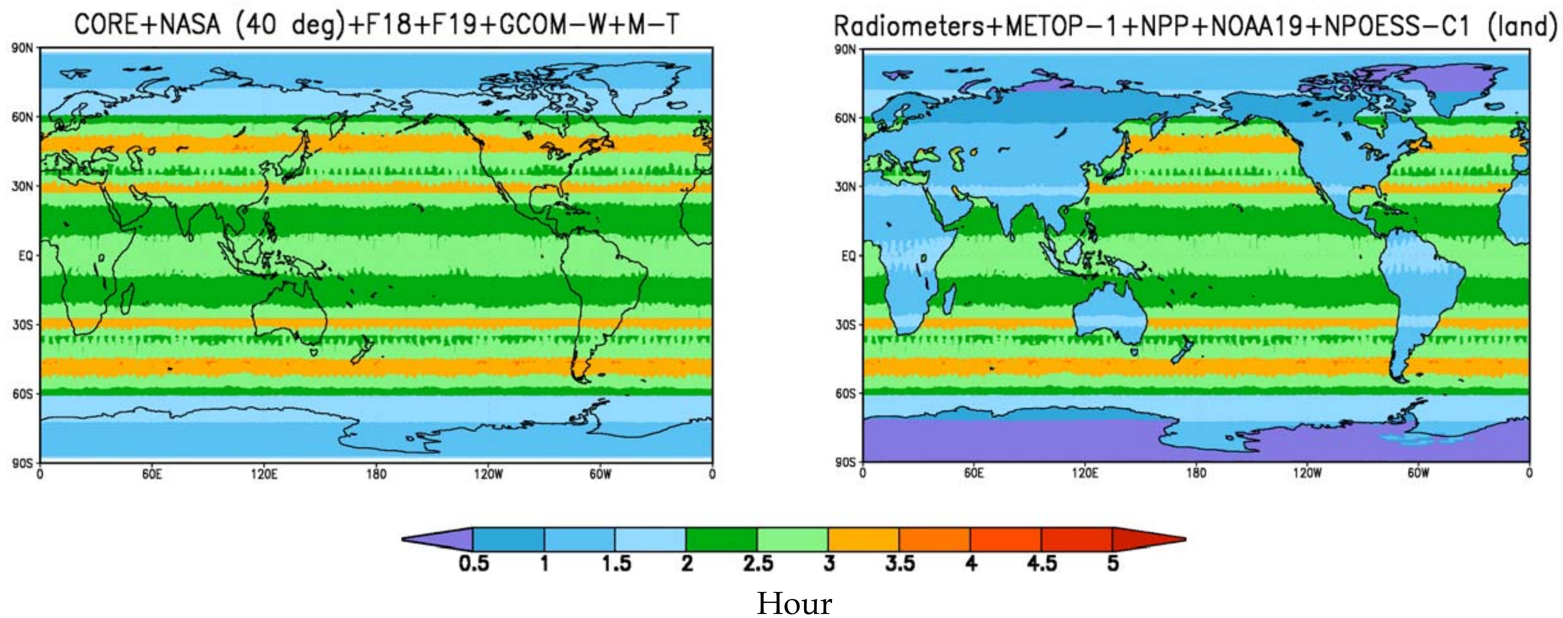
Average Revisit Times by Passive Microwave Sensors in GPM Era

6 Conically-Scanning Radiometers

(≤ 3h over 86% of globe)

6 Radiometers Plus 4 Cross-track Sounders (Over land)

(≤ 3h over 92% of globe)



GPM Core, NASA-1(40°), F18, F19 GCOM-W, Megha-Tropiques

With addition of MetOp-1, NPP, NOAA-19, & NPOESS-C1 over land

GPM Ground Validation Strategy & Plans

- ***Statistical validation sites*** *for direct assessment of GPM satellite surface precipitation products:*
  - Co-located with existing or upgraded national network (NEXRAD etc.) and dense gauge networks to identify and resolve significant discrepancies between the national network and satellite estimates
  - Leveraging off national networks of partnership countries and international scientific collaboration for regional and global assessments
- ***Precipitation process sites*** *for improving understanding and modeling of precipitation physics in physical and radiance spaces for satellite retrieval algorithm improvements:*
  - Continental tropical, mid- and high-latitude sites (including orographic/coastal sites and targeted sites for resolving discrepancies between satellite algorithms)
  - Oceanic tropical and mid-latitude sites
  - Aircraft measurements
- ***Integrated hydrological sites*** *for improving hydrological applications:*
  - Co-located with existing watersheds maintained by other US agencies and international research programs to use hydrological basins as an integrated measure of the quality of precipitation products

International GPM GV partnership opportunities

GPM Mission Status

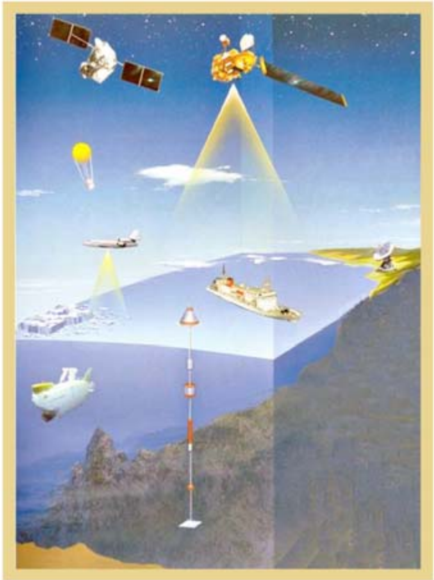
- *NASA and JAXA have signed an agreement to jointly formulate the GPM mission with the following assumptions:*
  - *JAXA to provide a Dual-frequency Precipitation Radar (DPR) for the GPM “Core” spacecraft and launch services for the Core spacecraft*
    - KuPR and KaPR engineering model under development & testing
  - *NASA to provide two GPM Microwave Imager (GMI)’s, the Core spacecraft, a constellation spacecraft & associated launch services*
    - GMI in development by Ball Aerospace Technology Corporation
    - Joint NASA and industry development of Core Spacecraft underway
- *GPM Core spacecraft launch in the 2013 timeframe*
- *Constellation partnership development*
  - *Partnerships in formulation: JAXA, NOAA, DoD*
  - *Partnerships under discussion: AEB (Brazil)*
  - *Future opportunities: ISRO(India)/CNES(France), ESA, EUMETSAT*
- *GPM Planning Workshops*
  - *5th GPM International Planning Meeting held in November 2005 in Tokyo, Japan. The next meeting is being planned for November 2006.*
  - *2nd GPM International Ground Validation Workshop held in September 2005 in Taipei, Taiwan. The 3rd GV Workshop is under planning for 2007.*

International Partnership: Key to GPM Success

GPM

- *International partnership in constellation assets, data exchange, ground validation, and collaborative scientific research is key to GPM success.*

- *GPM was identified by United Nations in 2002 as an outstanding example of peaceful uses of space - benefiting international scientific community and enabling important societal applications involving freshwater resources and environmental prediction.*



- *GPM implementation approach is prototype for the emerging Global Earth Observing System of Systems (GEOSS), an international effort to provide comprehensive, long-term, and coordinated observations of the Earth.*